Contrast Polarity in Letter Identification

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Question

Scharff and Ahumada (2002, 2003) measured paragraph readability and letter identification for light text and dark text. Responses to light text were slower (Figure 1) and less accurate for a given contrast.
Is this polarity effect
(1) the result of differences in the ON and OFF retinal pathways (Figure 2), or
(2) the result of more experience with dark text on light backgrounds?
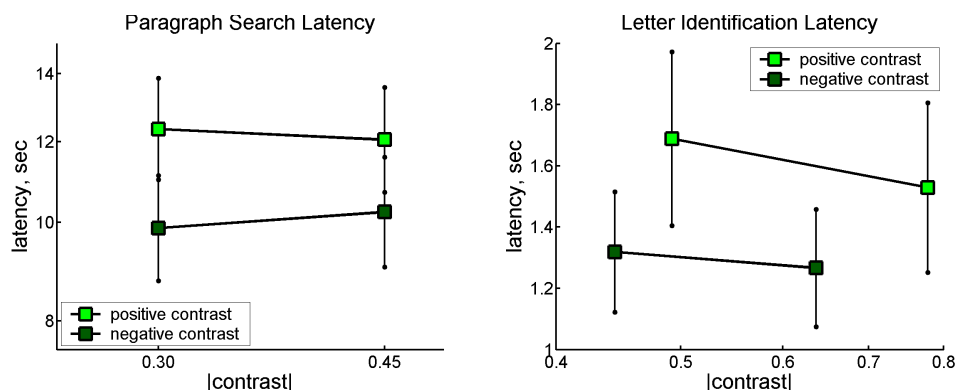

Figure 1: Latencies vs. contrast (left) paragraph word search (Scharff & Ahumada, 2002) (right) letter identification (Scharff & Ahumada, 2003). Error bars are 95% confidence intervals.
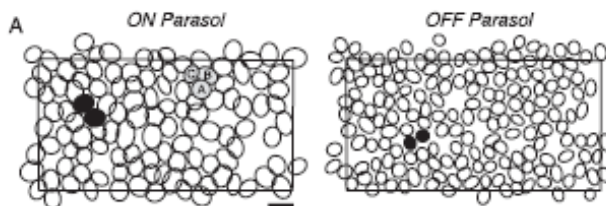

Figure 2: Peripheral ON and OFF receptive fields of Macaque parasol ganglion cells. Scale bar=200 µm (Shlens et al., 2006). The smaller size of the OFF cells might allow for finer resolution and, in turn, a processing advantage for letter identification.

Strategy

To help distinguish between these alternatives we separated the signal polarity from the perceived contrast polarity by a pedestal only slightly larger than the letters. The zero contrast letters were placed on a pedestal. The signal polarity was then the pedestal polarity, but the perceived letter polarity is in the opposite direction (Figure 3). If the physiological explanation holds, the polarity of the pedestal should control the performance rather than the polarity of the letters.
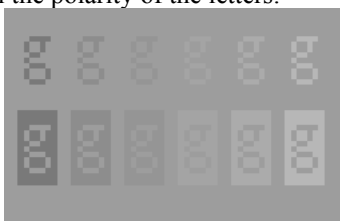

Figure 3: Upper. The letter g at six contrast levels (-0.4, -0.2, -0.1, 0.1, 0.2, 0.4).
Lower. The letter at zero contrast with the large background, and the pedestal at the above six contrast levels. The apparent contrast of the letter is opposite that of the pedestal.

Methods

Twelve 12 letters we used earlier (acegilnqrstu) were presented one at a time at a letter height (6 superpixels) of 0.2 deg, (with 1 superpixel = 4x4 pixels) on a background of 30 cd/m². Fourteen student observers identified the presented letter by typing it quickly. No feedback was given. We presented 4 randomized blocks of all 144 combinations of the 12 letters and the 12 contrast conditions of Figure 3.

Is Negative Contrast Predominant in the Negative Stimuli? Yes, but more for letters alone.

We simulated ON and OFF channels with balanced DoG filters with a center and surround spreads of 2 and 6 arc min, respectively (Ratliff et al., 2005). Letters alone averaged 87% of their filtered contrast energy in the channel with the letter polarity. Pedestal letters averaged 75% of their filtered energy in the pedestal polarity channel.
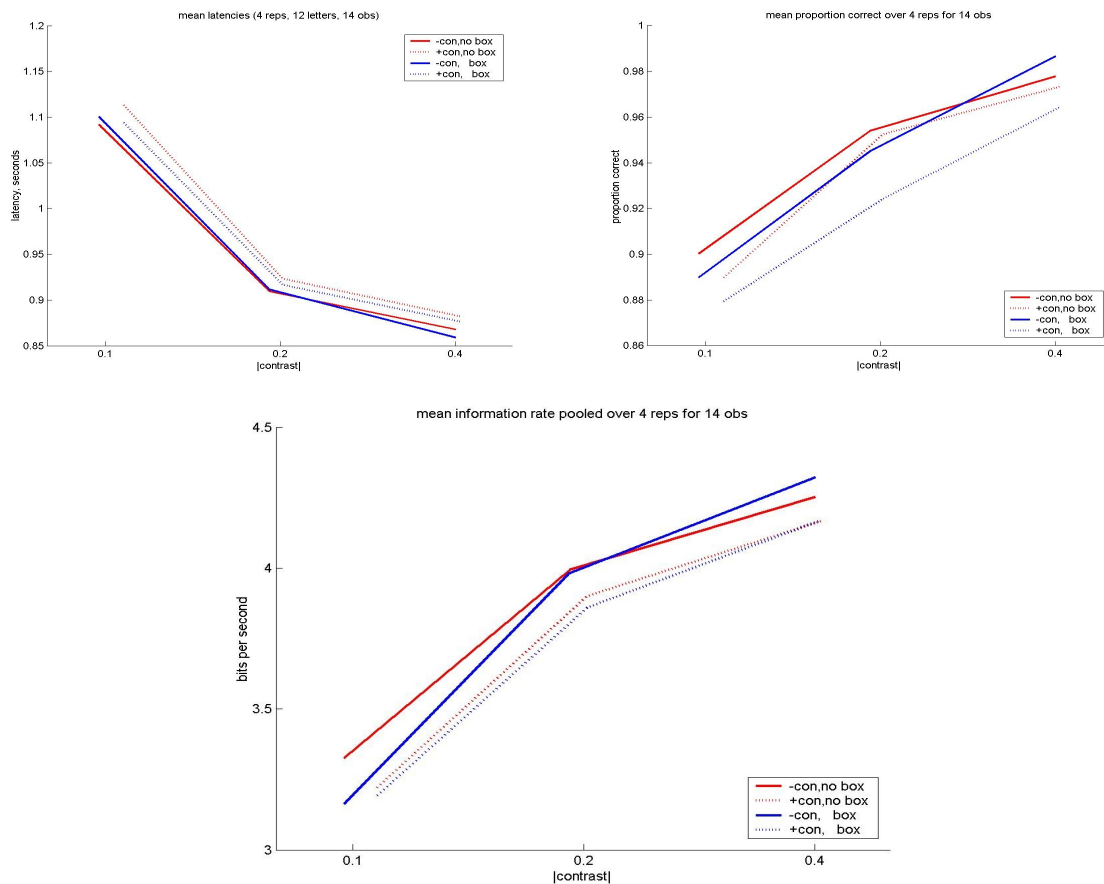
Figure 4: Mean latencies (left), proportion correct (right), and bit rates (below) versus contrast.

Results

Mean response latencies and accuracy (proportion correct) are shown above (Figure 4), along with bit rate (a combined speed and accuracy score computed from the information transmitted in the confusion matrix pooled over replications divided by the average latency). Without the pedestal (red), dark (solid lines) letters were identified at a higher bit rate; $F(1,13) = 7.0$, $p<.05$. With the pedestal (blue), dark (solid) pedestals were better. $F(1,13) = 6.3$, $p<.05$. Pedestal stimuli had lower bit rates than letter stimuli without pedestals. $F(1,13) = 9.0$, $p<.05$.

Conclusions

Polarity of the signal energy, not the apparent text contrast, determines performance, supporting the hypothesis that the off channel is more effective at transmitting the letter information than the on channel against the hypothesis that observers do better with dark-appearing letters because they have more experience with them. Performance with the pedestal letters was worse. This is consistent with the reduced contrast energy at the signal polarity, masking of the box, and reduced experience.

Acknowledgements

References

Ratliff, Sterling, and Balasubramanian (2005) Negative contrasts predominate in natural images, ARV0 e-Abstract 4685.
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Shlens, Field, Gauthier, Grivich, Petrusca, Sher, Litke, & Chichilnisky (2006) The structure of multi-neuron firing patterns in primate retina. J. Neuroscience, 26(32), 8254–8266.